

Seismic Hazards Investigation of Puget Sound (SHIPS): Collaborative Research with the U. S. Geological Survey, Oregon State University, University of Texas at El Paso, University of British Columbia, University of Washington, University of Victoria, Pacific Geoscience Center

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Element II

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Introduction

The overall objectives of the Seismic Hazards Investigation of Puget Sound (SHIPS) are to understand both earthquake effects (the influence of the regional velocity structure on strong ground motion) as well as the distribution and size of earthquake sources (fault locations and geometry) in this urban area. The cities of Olympia (state capital), Seattle, Tacoma, Everett, Bellingham, and Victoria (Provincial Capital) and Vancouver, Canada are underlain in part by thick sequences of Cenozoic sedimentary rocks that amplify and focus seismic energy, thus increasing ground shaking during an earthquake. SHIPS involves the acquisition of wide-angle seismic refraction and reflection data. These data will be used in mapping and modeling areas of expected strong ground shaking, and to better determine the regional velocity structure and tectonic framework of the Puget Sound Region.

In this report, we review the progress to date in analyzing seismic data acquired at land receiver stations in March 1998, during the marine component of the experiment. Seismic recording of land sources is scheduled for May of 1999.

Data Acquisition and Analysis

Data acquisition for the marine component of SHIPS was completed in late March of 1998. During this phase, an air gun array totaling 6700 in³, towed by the R/V Thompson, was fired in

Puget Sound, Hood Canal, the Straits of Juan de Fuca, and Georgia Straits (Figure 1). Nearly 33,000 Airgun shots were recorded by a towed 2.4-km streamer, 10 ocean-bottom seismographs, and approx. 260 land seismographs. In addition, the Canadian research ship, Tully partnered with the Thompson to collect two-ship expanding spread profiles along selected lines. The weather was unseasonably favorable for the experiment, and analysis of the data to date suggests that data quality is outstanding. The data contain both pre-critical reflection and wide-angle reflection and refraction events.

Data from the land was reduced and archived as receiver gathers in SEG-Y format with geometry over the summer of 1998 at the PASSCAL instrument center at Stanford University. The data reduction effort was led by Tom Brocher from the U.S. Geological Survey. All institutions involved in SHIPS contributed to this effort. Three archival copies of the data were made: one for the IRIS Data Management Center, one to be archived at the U. S. Geological Survey, and one for individual investigators. Data for each station were archived as 11 different files. Each file contains records corresponding to a portion of the ship tracks. Traces within the files are 90 s long with a sample rate of 100 Hz. Geometry information, including the latitude and longitude of the shot, the latitude and longitude of the receiver, and the range between shot and receiver is recorded in each trace header.

Preliminary Results from the Tacoma Basin

Data from SHIPS is being analyzed by a large group of investigators. At the University of Texas at El Paso, we are analyzing data from land stations near the Tacoma basin in order to better define the velocity structure of this basin. This study includes data from approximately 50 land stations that recorded shots in Puget Sound and Hood Canal.

Previous interpretation of seismic reflection data (Pratt et al., 1997; Figure 2) suggests that the Tacoma basin lies within a syncline associated with a northward moving fold and thrust sheet. The basin is bounded on the north by the Seattle uplift, and to the south by the Black Hills uplift. Analysis of the seismic reflection data suggest that the Tacoma basin contains about 3.5 km of Cenozoic fill, assuming an average seismic velocity of 3.5 km/s for the sediments. The basin is floored by volcanic rocks of the Crescent Formation. This thickness estimate for the Tacoma basin fill is consistent with previous estimates from gravity modeling which indicated that the basin is as much as 4 km thick (Danes et al., 1965; Finn, 1990). A lack of reliable velocity information means that the actual thickness of the Tacoma basin remains in question. In addition, the geometry and origin of the basin boundaries remain unconstrained, as only the northeast boundary is well imaged by seismic reflection data at the Seattle uplift.

Preliminary analysis of the seismic data shows that it is well suited to the task of defining the velocity structure of the Tacoma basin. First arrivals are typically well defined to offsets of 30-40 km (Figure x) and sometimes to as much as 60-70 km. 1-D velocity modeling of a number of the stations along line 2 shows that the Tacoma basin is approximately 2.5 to 3 km thick and that the basin fill has a velocity of 2 to 2.5 km/s. The underlying Crescent Formation has apparent velocities of 6 to 6.5 km/s. If these results hold up with more detailed modeling, then the new data suggests that the basin contains lower velocity fill and that it is shallower than previously thought.

Future data analysis will include a 3-D inversion of the arrival times in and around the Tacoma basin to define its velocity structure as well as gravity modeling.

References

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Non-Technical Summary

The Seismic Hazards Investigation of Puget Sound (SHIPS) is a seismic study designed to help understand the possible effects of earthquake as well as the distribution and geometry of active faults in urban areas of the Puget Sound region. This is particularly important since the cities of Olympia, Seattle, Tacoma, Everett, Bellingham, and Victoria, and Vancouver, Canada are underlain in part by thick sequences of Cenozoic sedimentary rocks that amplify and focus seismic energy, thus increasing ground shaking during an earthquake. Preliminary analysis of new data from SHIPS suggest that the Tacoma basin maybe shallower and contain lower velocity sediments than previously thought.

Reports Published

Hiett, B. J., K. C. Miller, T. M. Brocher, and the SHIPS Working Group, 1998, The 1998 Seismic Hazards Investigation in Puget Sound (SHIPS): Results From the Tacoma Basin, Western Washington, abstract presented at the 1998 Fall Meeting of the American Geophysical Union, San Francisco.



Figure 1. Overview of SHIPS experiment showing study area and ship tracks (red and blue lines in waterways). More than 33,000 airgun shots were recorded by 260 temporary seismic (Reftek and OBS) stations to offsets exceeding 370 km. Receivers were deployed along the Strait of Georgia, along the Strait of Juan de Fuca, throughout the Puget Lowland as far south as Chehalis, on the eastern flank of the Olympic mountains, and on the western flank of the Cascadia arc. Basemap courtesy M. Hamer, USGS.

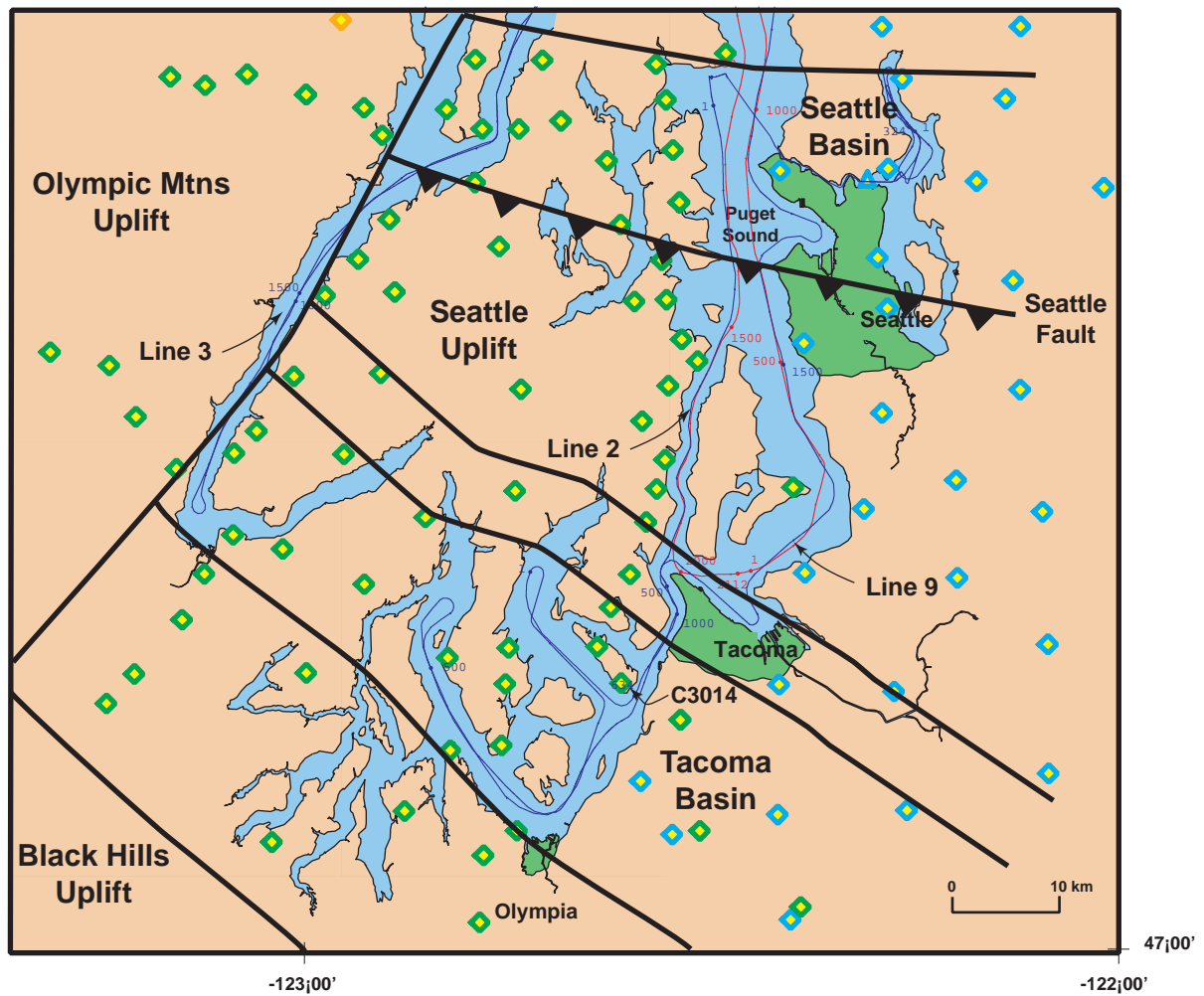


Figure 2. Map showing land recording stations with respect to ship tracks (red and blue line)s and geology from Pratt et al., (1997). Diamonds indicate recording station locations: green outlines - USGS stations, blue outlines - Univ. of Washington stations. Thick black lines indicate faults and axial surfaces of folds as defined by Pratt et al. (1997). The seismic data recorded at station C3014 from line 2 is displayed in Figure 3. Basemap courtesy M. Hamer, USGS.

Station C3014 - Shot Line 2

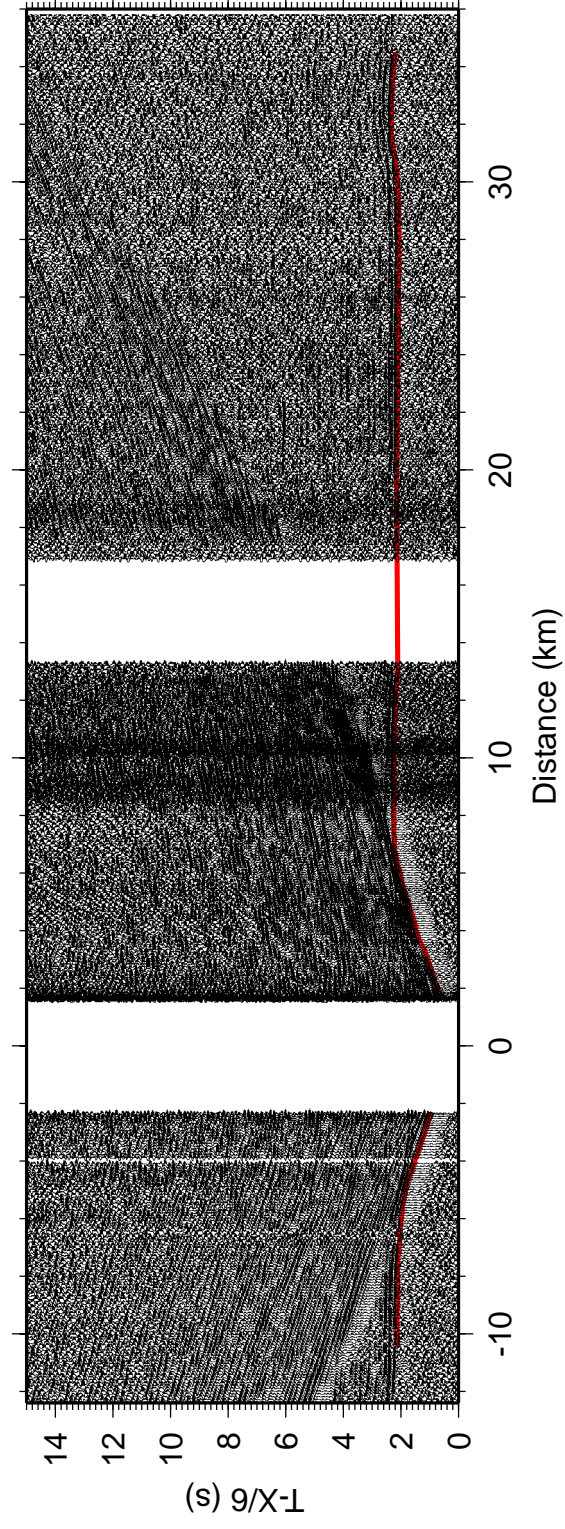


Figure 3. Seismic data from line 2 shots at station C3014 (Figure 2). First arrivals (red line) from Crescent Formation overtake arrivals from basin sediments at 5 to 7 km offset.